Space Human Factors Engineering Research Benefits to Programs

Computer-Aided Human Factors Analysis Modeling

December 2004

Provided by
Graphics Research and Analysis Facility and
Lighting Environment Test Facility

Selected Projects

- Radiance Lighting Math Model
- Human Task Performance Evaluation with Luminance Images
- Improving Human Task Performance with Luminance Images and Dynamic Overlays
- Utilization of the Space Vision System as an Augmented Reality System for Mission Operations
- Enhanced Lighting Techniques and Augmented Reality to Improve Human Task Performance

Selected Projects (continued)

- Cupola Crew Restraints
- Crew Quarters
- Wardroom
- Human Research Facility
- Treadmill with Vibration Isolation & Stabilization
- STS-90 Modeling

Overview

- Research:
  - CDDF and Core Support to develop Radiance Lighting Math Model (1995)
  - “Human Task Performance Evaluation With Luminance Images” NRA 95-OLSMA-01 (1996-98)
  - “Improving Human Task Performance with Luminance Images and Dynamic Overlays” NRA 98-HEDS-01 (1998 – 2000)
  - “Utilization of the Space Vision System As An Augmented Reality System For Mission Operations”, Technology Development Project (TDP) (2003)
  - “Enhanced Lighting Techniques and Augmented Reality To Improve Human Task Performance”, NRA (to be completed Sept 2005)

Overview (continued)

- Application:
  - Application of math model to optimize exterior lights and interior rack finish provides cost savings
  - Integration of Camera Model parameters into Radiance Lighting Model
  - Application of lighting in Training

- Results:
  - Development of system to optimally select cameras and lights for on-orbit operations (1998-99)
  - Integration of lighting effects in NASA System Engineering Simulator (2001-2003)
  - Augmented Reality (AR) Technology can be used on flight hardware

Radiance Lighting Math Model

- Research:
  - Center Director Discretionary Fund (CDDF) Project (1995-1996)
  - Core Research Support (1994-1996)

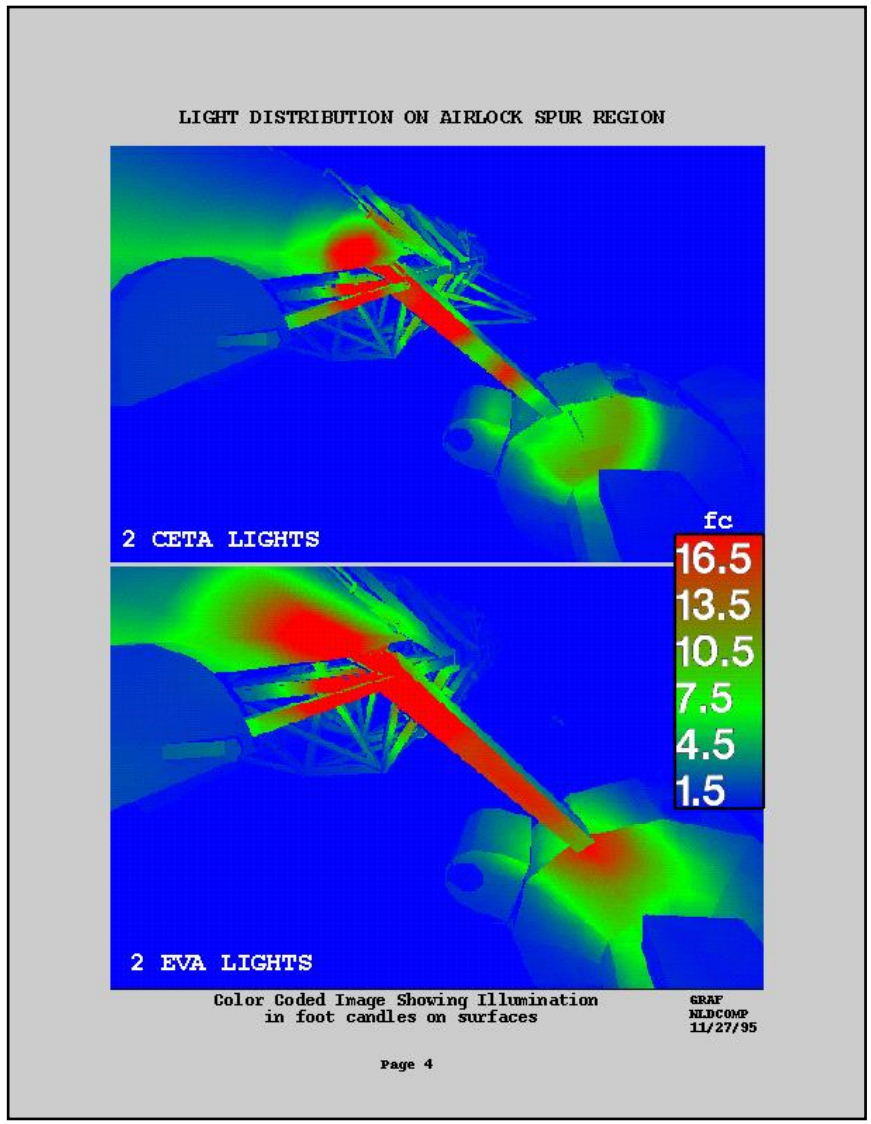
- Application:
  - Radiance is developed into a NASA lighting math model using NASA specific database of lights and materials. Now a registered and configuration controlled math model for mission support.

- Results:
  - Optimized the number exterior fixed lights for EVA translation on ISS (reduced from 14 to 7)
  - Analytically determine the impact on ISS interior lighting levels for a family of rack face surface coatings.

Exterior Luminaire Evaluation Using Radiance Lighting Math Model

The goal was to evaluate the location and number of external fixed luminaires or lights required for extra-vehicular activity at key translation paths.

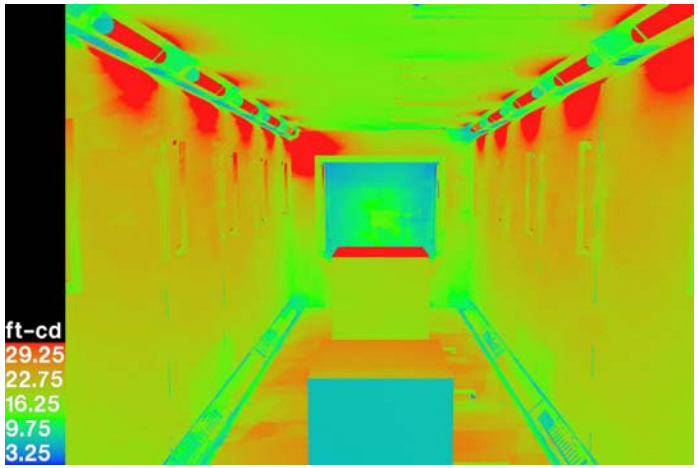
The evaluation determined that the number of luminaires can be safely reduced by 50%, reducing installation and maintenance costs for the Space Station.



Comparison of Two Types of Rack Surfaces as it Impacts Overall Illumination

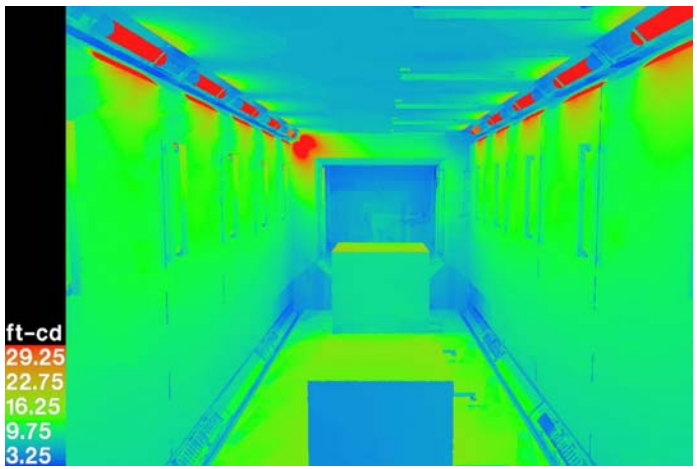
A267 Semi-gloss White Paint as Rack Surface Finish

Average Centerline Illuminance: 28 foot-candles



Clear Anodized Aluminum

Average Centerline Illuminance: 15 foot-candles



Human Task Performance Evaluation with Luminance Images

- Research:
  - "Human Task Performance Evaluation with Luminance Images" NRA 95-OLSMA-01 (1996-98)

- Application:
  - Development of synthetic camera images from luminance maps for use in training.
  - Comparison of the effect of different types of training images on actual task performance.
  - Synthetic camera images from luminance maps provide an analytical basis for matching cameras and lighting for on-orbit tasks. Integrated into Radiance Lighting Model.

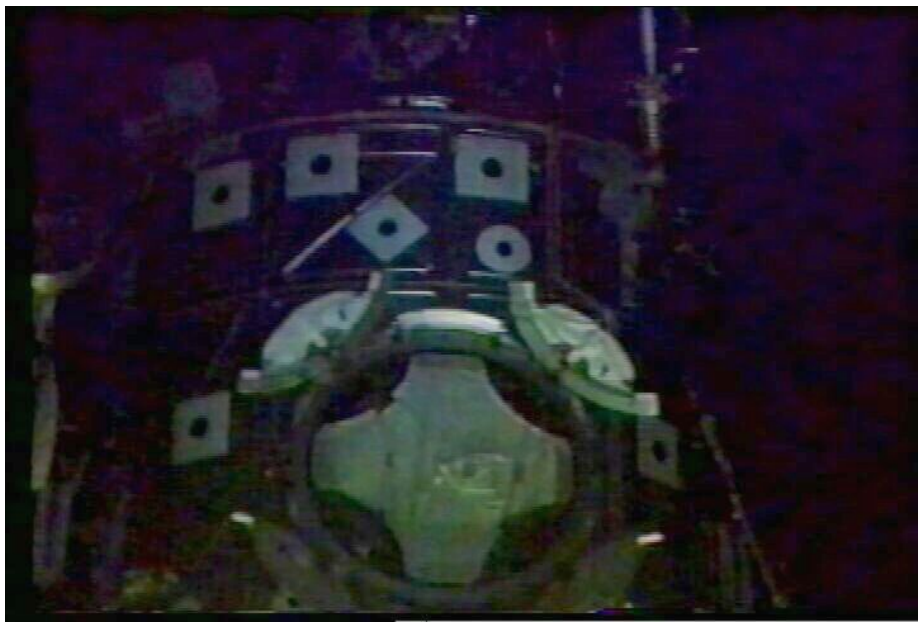
Human Task Performance Evaluation with Luminance Images

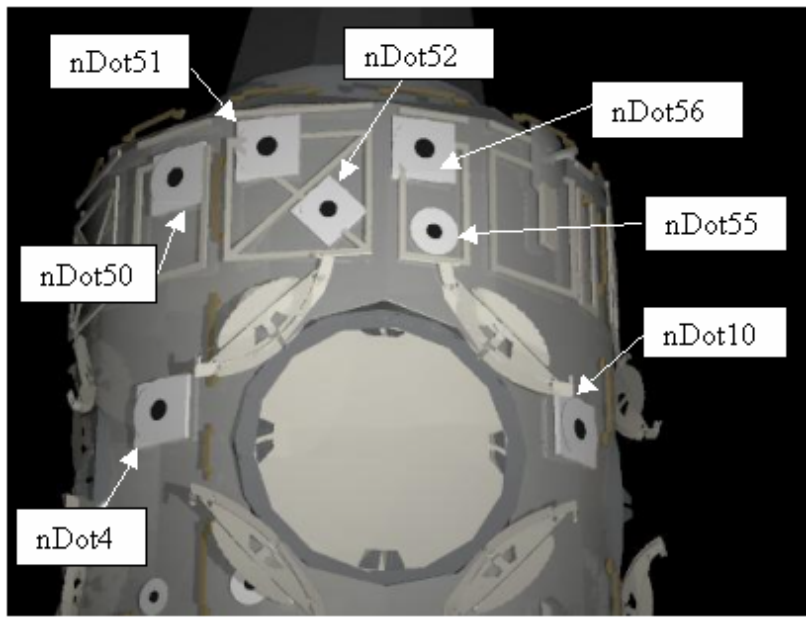
- Results:
  - Lighting Math Model is used to predict lighting condition and camera selection for ISS assembly berthing operations (Flights 2A.1 - 11A).
  - Training with camera images of static simulated lighting improves human performance.

Human Task Performance Evaluation with Luminance Images

	Target Id	Predicted Min. Foot Lamberts	Shadow on target	Critical	Camera Choice
Node	nDot4	0.37	no	yes	ITVC, CTVC
Node	nDot50	0.30	no	yes	ITVC, CTVC
Node	nDot51	0.34	no	yes	ITVC, CTVC
Node	nDot52	0.49	no	yes	ITVC, CTVC
Node	nDot55	0.48	no	yes	ITVC, CTVC
Node	nDot56	0.39	no	yes	ITVC, CTVC
Node	nDot10	0.21	no	yes	ITVC

Night - Node 1 Target Array for Z1 Installation - LED Light from B, C, Keel (Xo = 715), and RMS Elbow Camera





Example analysis determining camera type based on predicted luminance values on targets during berthing operations

Improving Human Task Performance with Luminance Images and Dynamic Overlays

- Research:
  - "Improving Human Task Performance with Luminance Images and Dynamic Overlays" NRA 98-HEDS-01 (1998 – 2000).

- Application:
  - Determine the effects of dynamic vs static lighting on training and the effectiveness of augmented reality technology for training and task execution.
    - Lighting effects in training benefit performance whether dynamic or static.
    - Augmented Reality Technology improves operator performance during task execution.
- Result:
  - Integration of simple lighting effects in NASA JSC System Engineering Simulator (SES) for crew training (2001-2003)

Utilization of the Space Vision System as an Augmented Reality System for Mission Operations

- Research:
  - "Utilization of the Space Vision System as an Augmented Reality System For Mission Operations", Technology Development Project (TDP) (2003)

- Application:
  - Determine whether augmented reality technology can improve performance when implemented using existing flight hardware.

Space Vision System Hardware Currently aboard Shuttle and ISS

Utilization of the Space Vision System as an Augmented Reality System for Mission Operations

- Results:
  - SVS has been shown to be a capable 3D augmented reality platform with potential applications in robotic training, an additional resource for an ongoing NRA project and possible on-orbit robotic experiments.
  - Appropriate augmented reality overlays have been shown to offer significant improvements in robotic control performance.
  - Hand controller reversal and overshoot error frequencies have been introduced as metrics that may prove useful in robotic training and task evaluation.

Enhanced Lighting Techniques and Augmented Reality to Improve Human Task Performance

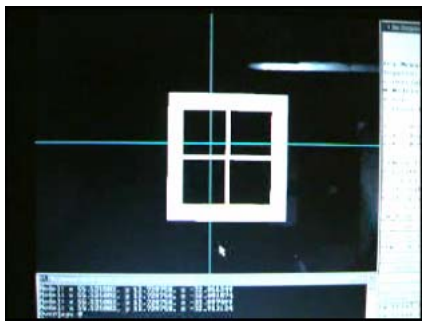
- Research:
  - "Enhanced Lighting Techniques and Augmented Reality to Improve Human Task Performance", NRA (to be completed Sept 2005)

- Application:
  - Determine how augmented reality technology can improve performance with poor visibility conditions on a major robotic system.
  - The Dexterous Manipulator Trainer (DMT) at NASA JSC is being used to determine the degree of operator performance improvement.

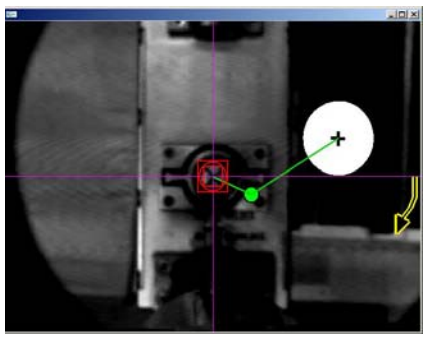
- Result:
  - l

Enhanced Lighting Techniques and Augmented Reality to Improve Human Task Performance

- Results:
  - Pilot testing for the current project (2005) has shown that significant improvement in performance is possible for a 6 degree of freedom task using augmented reality techniques.



Dexterous Manipulator Trainer end-effector is at close range to grapple fixture, note the illumination quality has degraded, but augmentation of alignment guide is still useful.



Tracking overlay will be used when field of view of end effector camera is restricted.

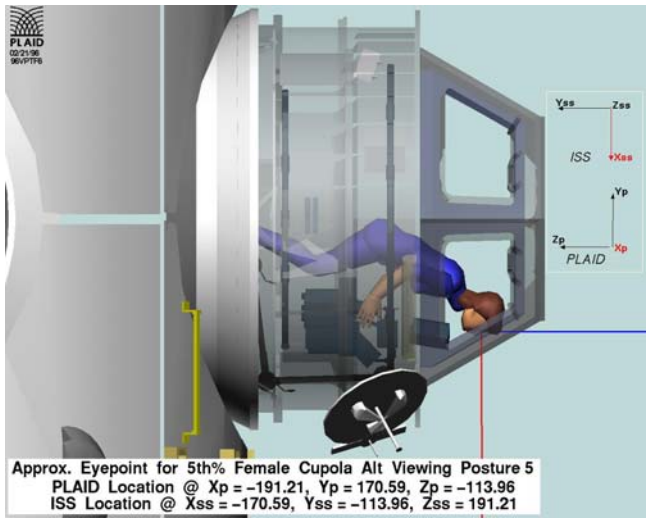
Computer-Aided Human Factors Analysis Modeling

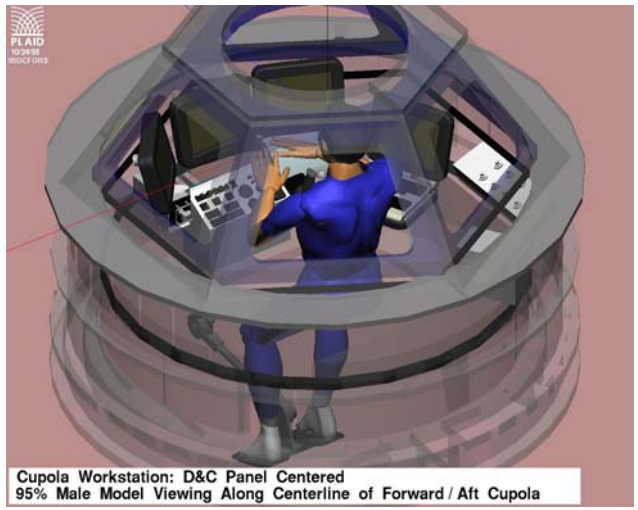
- Research:
  - Core support for research in human modeling has improved basic ergonomics analysis. 3-D graphics tools for 0-g; characterization of neutral body posture.
- Application:
  - Habitability analyses for designs of the ISS facilities such as:
    - Cupola (1996-2003)
    - Human Research Facility (HRF) (1996-1998)
    - Crew Quarters (1996-1999)
    - Wardroom (2000-2002)
    - STS-90 SpaceLab (1998-1999)
- Results:
  - Shown on the following pages

Computer-Aided Human Factors Analysis Modeling Cupola Crew Restraints

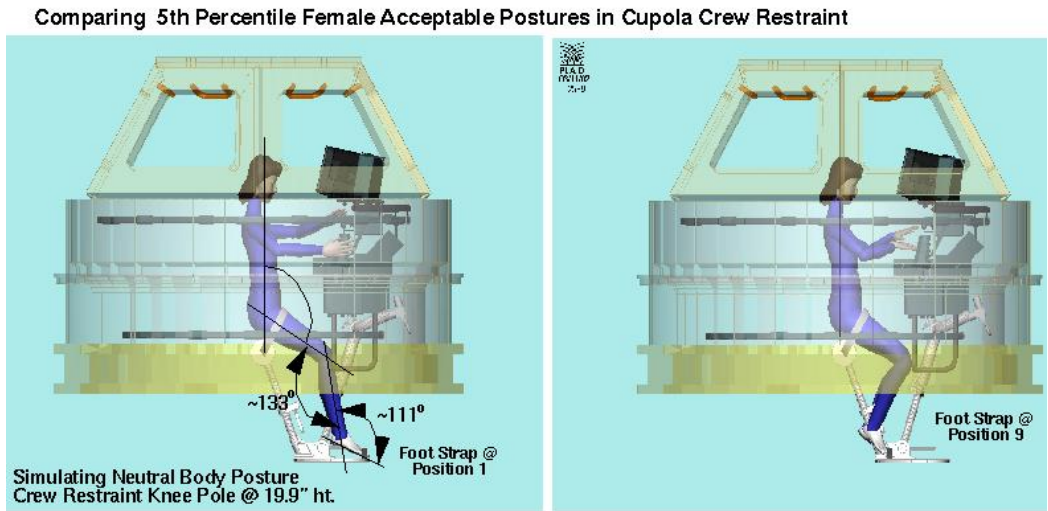
- Proposed viewpoints were analyzed for crew member line of sight for visualization of cupola workstation and through cupola windows while restrained.
- Examined crew member in crew restraint compared to acceptable neutral body posture, relative to Knee Pole and T-Tube adjustments of restraint components.

Computer-Aided Human Factors Analysis Modeling Cupola Crew Restraints (cont.)





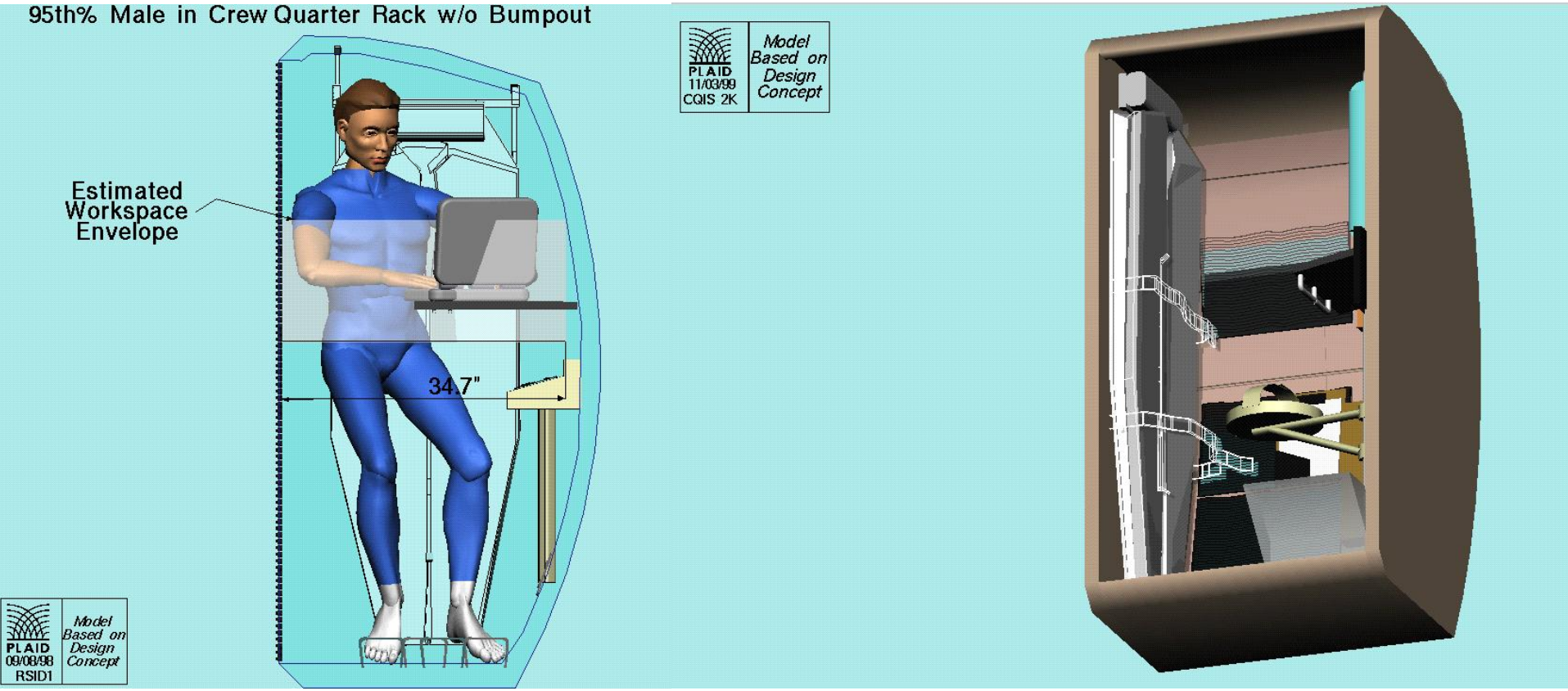
Cupola models demonstrate crew restraints and postures for the 5th Percentile Female.



Computer-Aided Human Factors Analysis Modeling Crew Quarters

- Provided the final estimated workspace envelope for 95th Percentile without the bumpout.
- Rack-based crew quarters were developed for versatility relative to bumpout door, sleep station, and working area laptop surfaces.
- In addition, there were proposed outfitting components such as stowage bags, personal care items, communication outlets, etc.
- There was further examination of the rackless concept in order to consider the possibility of radiation protection layers

Computer-Aided Human Factors Analysis Modeling Crew Quarters

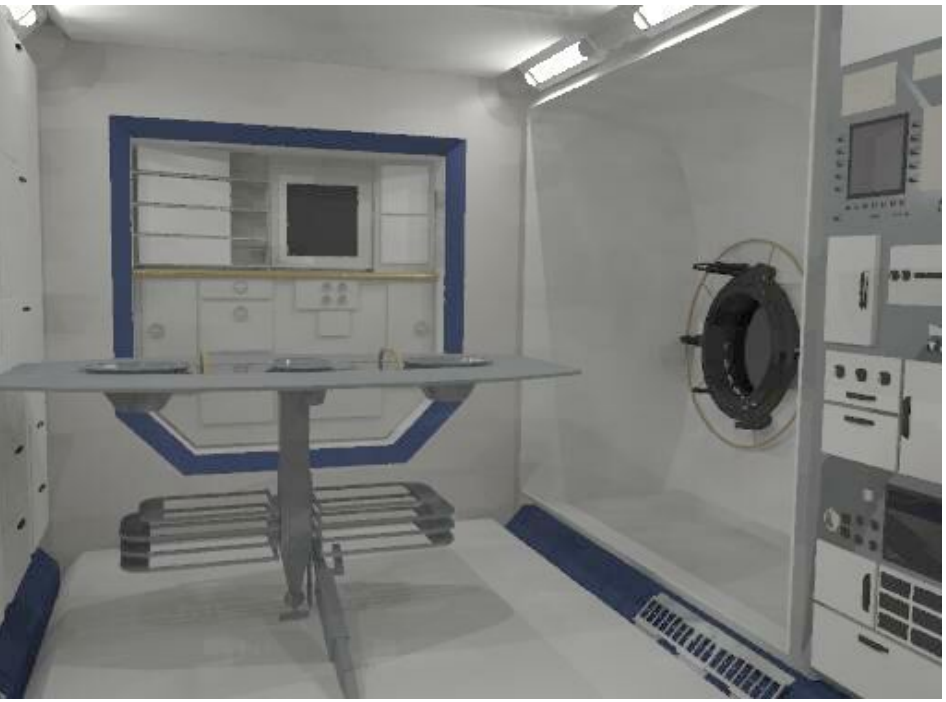


Model of the estimated workspace envelope for the 95th Percentile American male in the Crew Quarter Rack without the bumpout.

Computer-Aided Human Factors Analysis Modeling Wardroom

- Various proposed wardroom concepts were modeled to fit in the Habitability module endcone area.
- Several versions of the wardroom table with alternate crew restraint systems were examined in order to accommodate the 7-member crew.
- The layout of the wardroom area was examined for the appropriate positioning of the Habitability module window for crew accessibility, both from restrained positions and while in free floating postures.
- Habitability lighting in wardroom area was examined for different types of interior lights to accommodate full crew visibility.

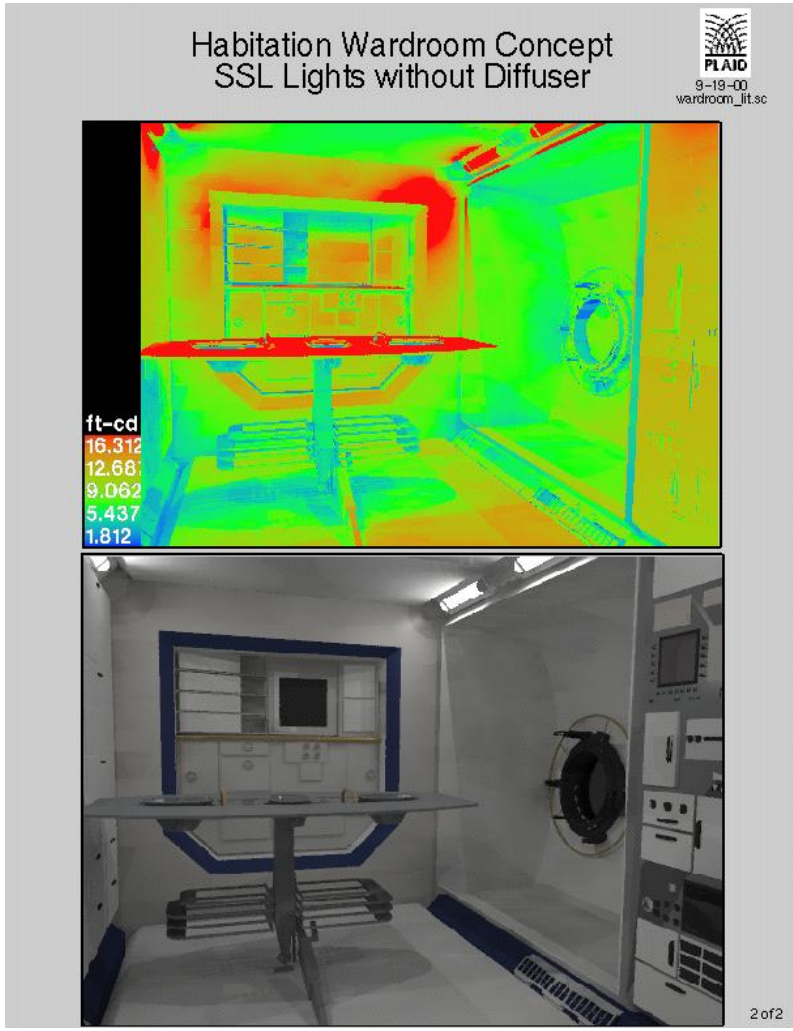
Computer-Aided Human Factors Analysis Modeling Wardroom



Wardroom Lighting Model

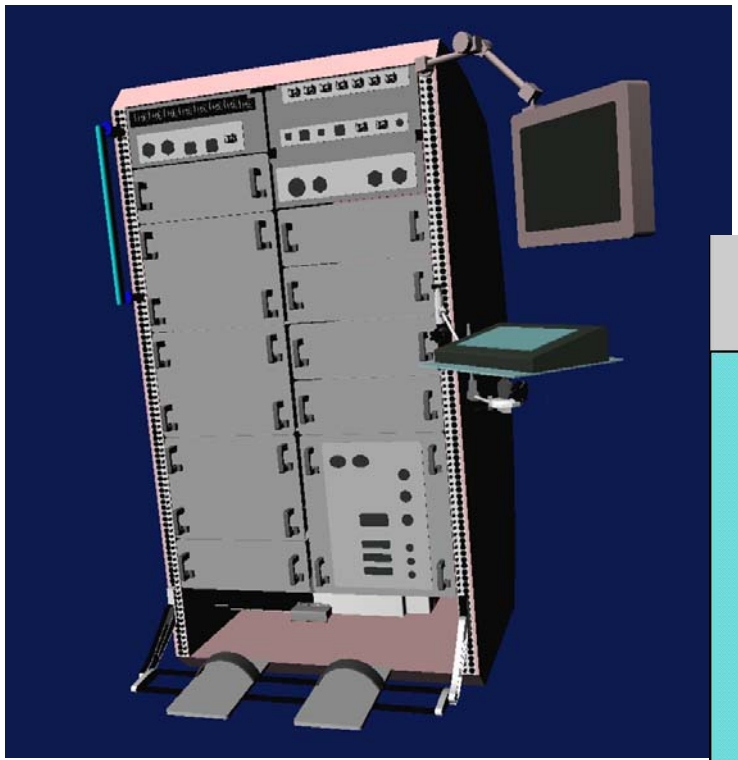
Wardroom Model with Crew to demonstrate the affects of body shadowing and window viewing possibilities

Computer-Aided Human Factors Analysis Modeling Wardroom

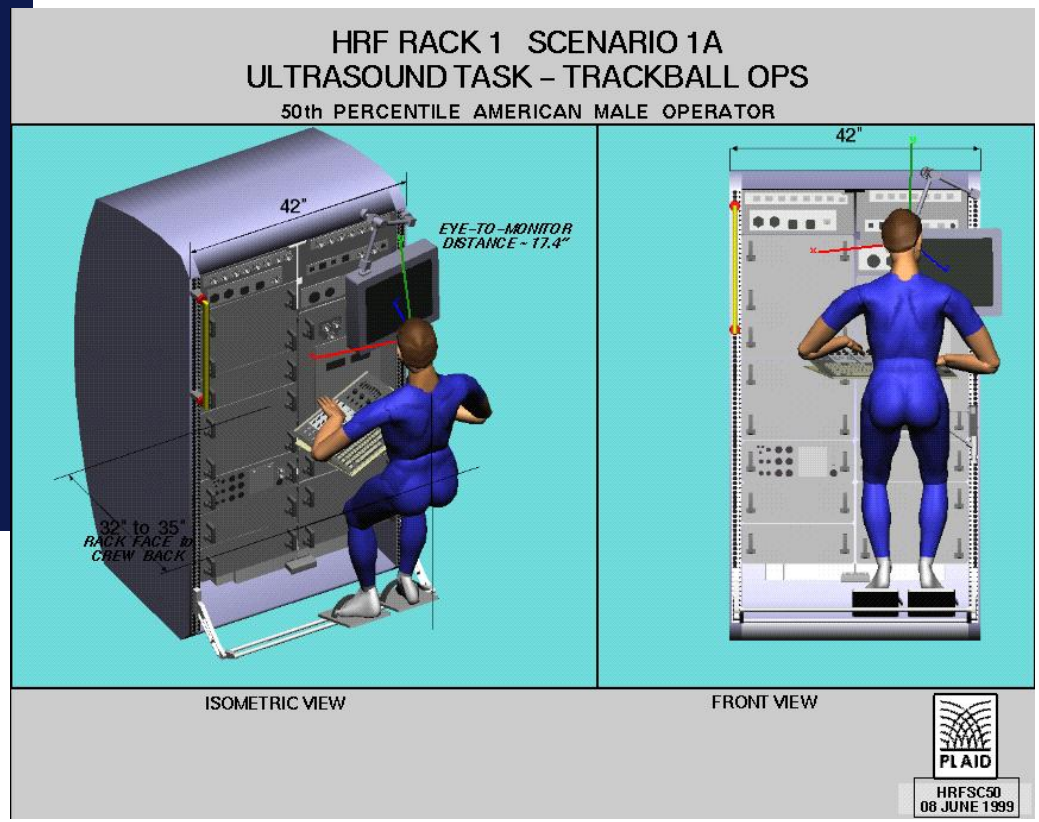


Wardroom Model with Crew (above).
Wardroom lighting model (right).

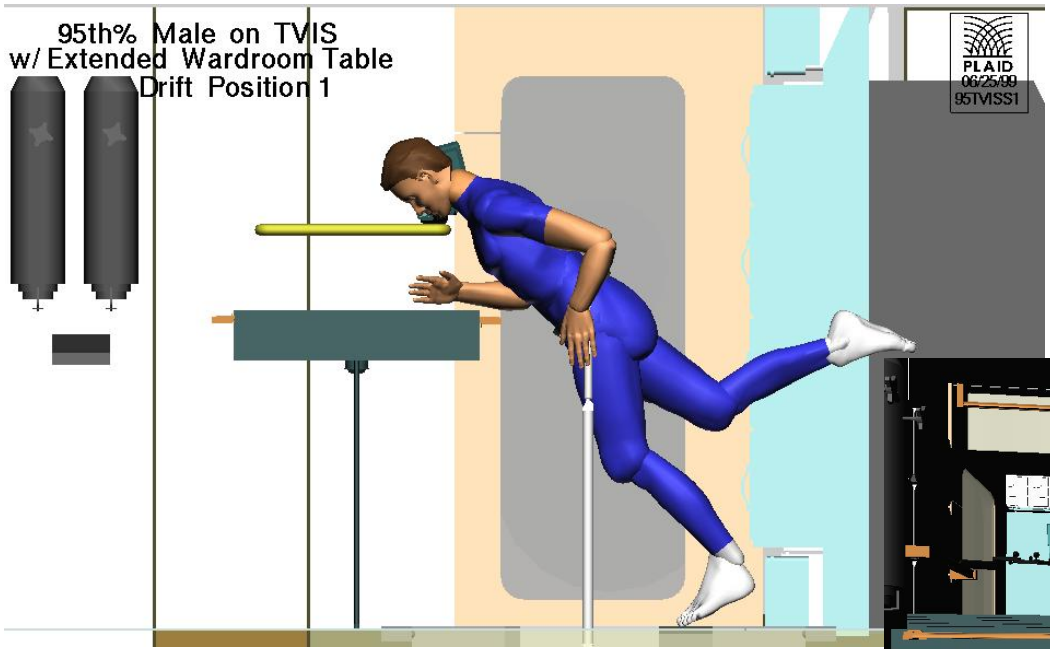
Computer-Aided Human Factors Analysis Modeling Human Research Facility



Model identified access conflicts during HRF operations prior to Critical Design Review (CDR), enabling re-layout of units in rack.



Computer-Aided Human Factors Analysis Modeling Treadmill with Vibration Isolation & Stabilization

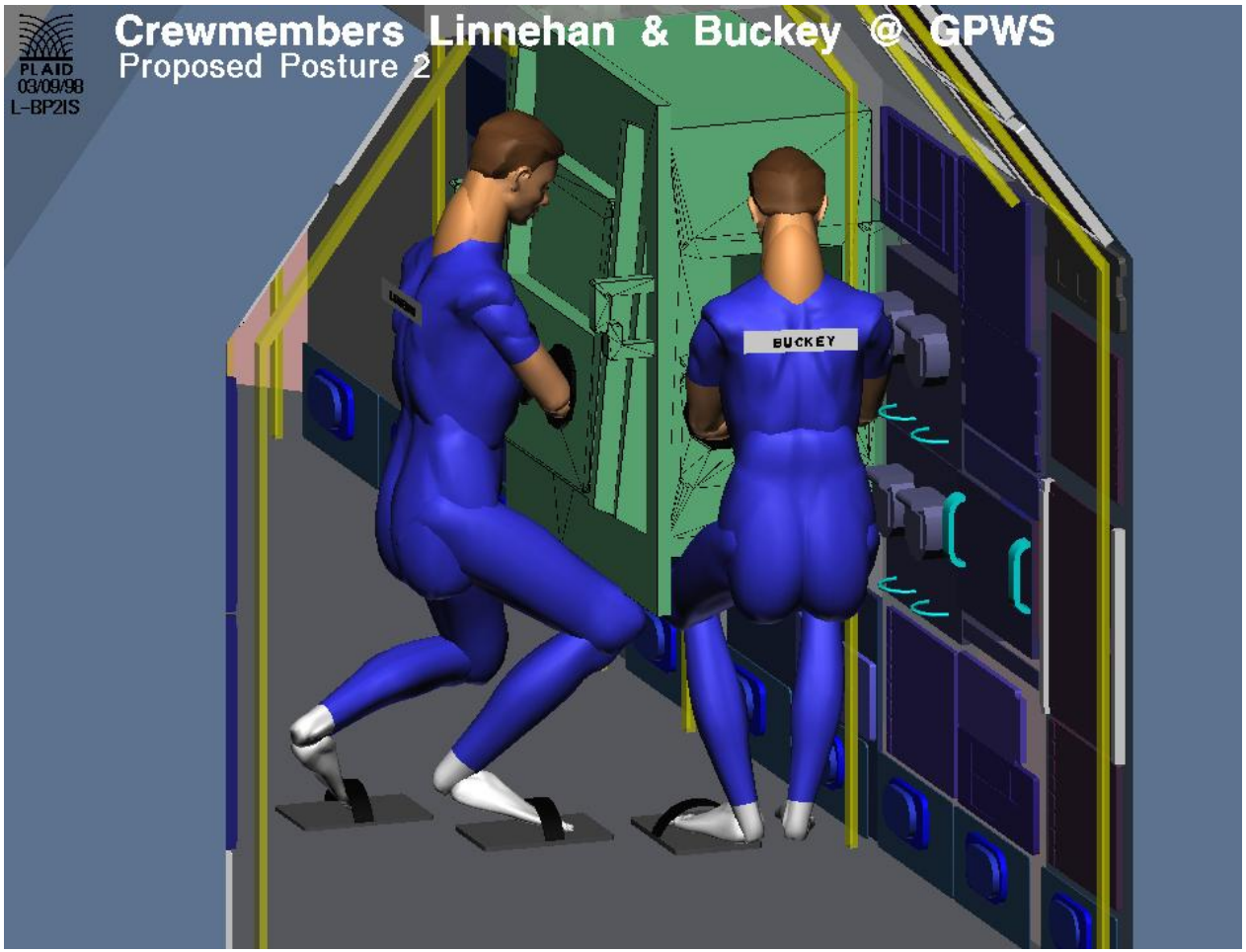


Model of 95th Percentile male using TVIS with the extended wardroom table in position.

Computer-Aided Human Factors Analysis Modeling STS-90 Modeling

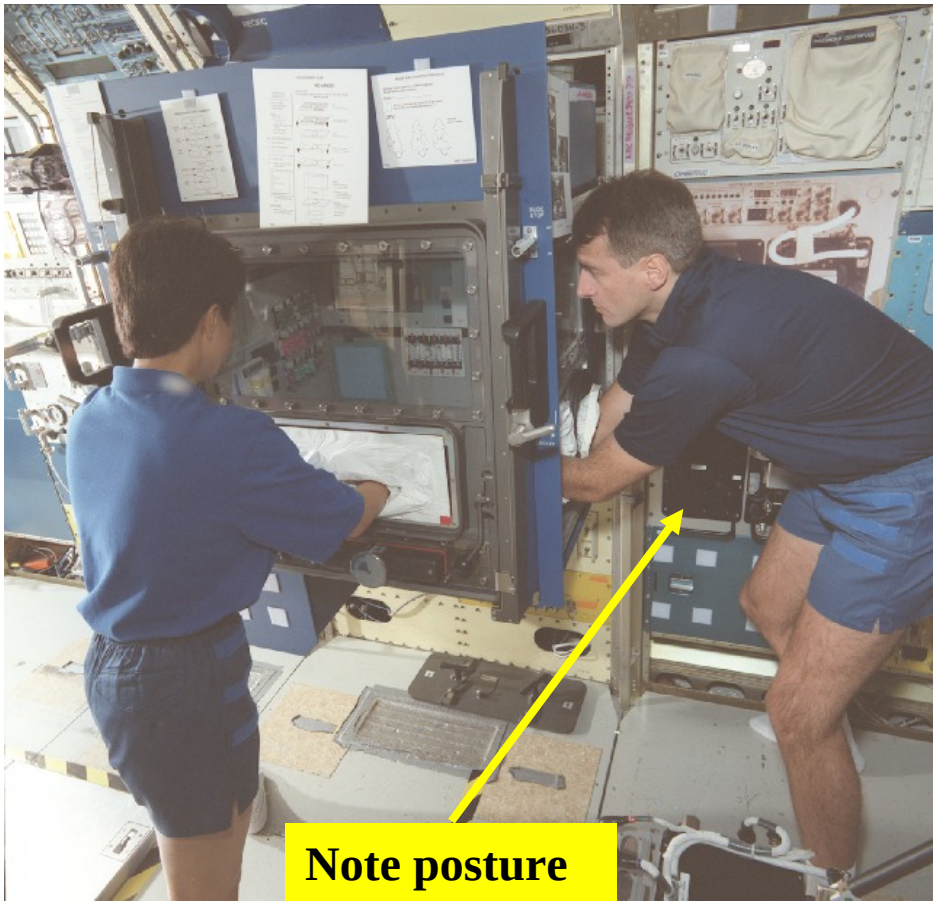
- Glovebox on STS-90 mounted close to ‘floor’ of SpaceLab. Tall crew members required to work at it for hours at a time.
- Anthropometric data maintained by Graphics Research and Analysis Facility (GRAF) and Anthropometry and Biomechanics Facility (ABF) was used with human modeling to determine the most comfortable working positions prior to flight.
- The model identified the configuration with the most appropriate postures so that tasks performed at the glovebox would not cause excessive strain and injury.

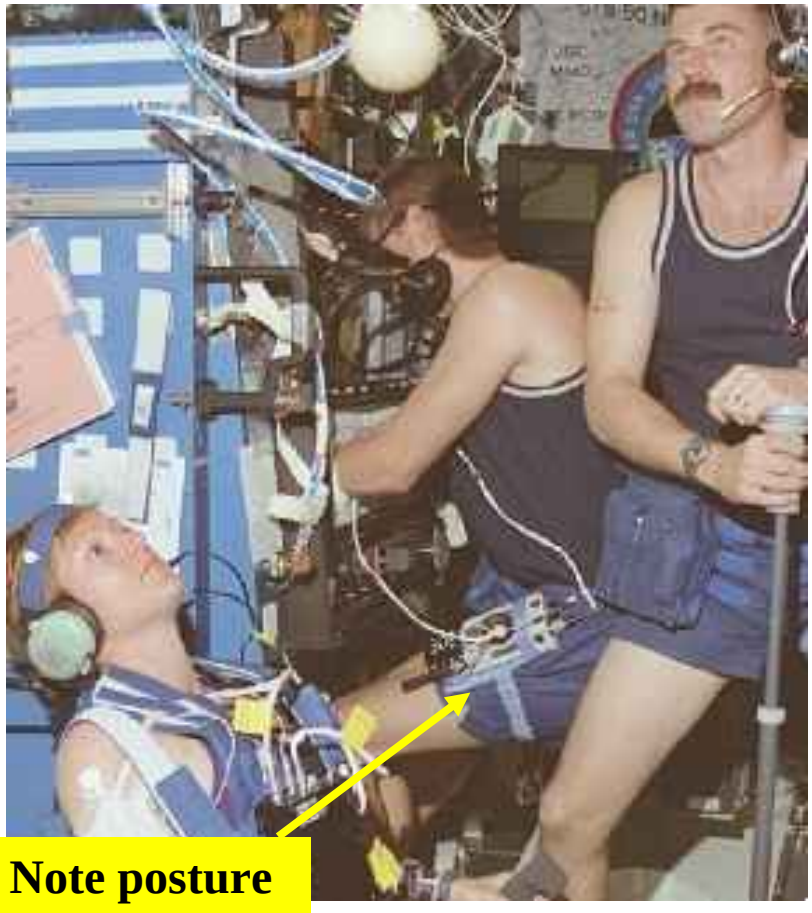
Computer-Aided Human Factors Analysis Modeling
STS-90 Modeling (cont.)



Graphical Model Depicting a Good Configuration

Computer-Aided Human Factors Analysis Modeling
STS-90 Modeling (cont.)

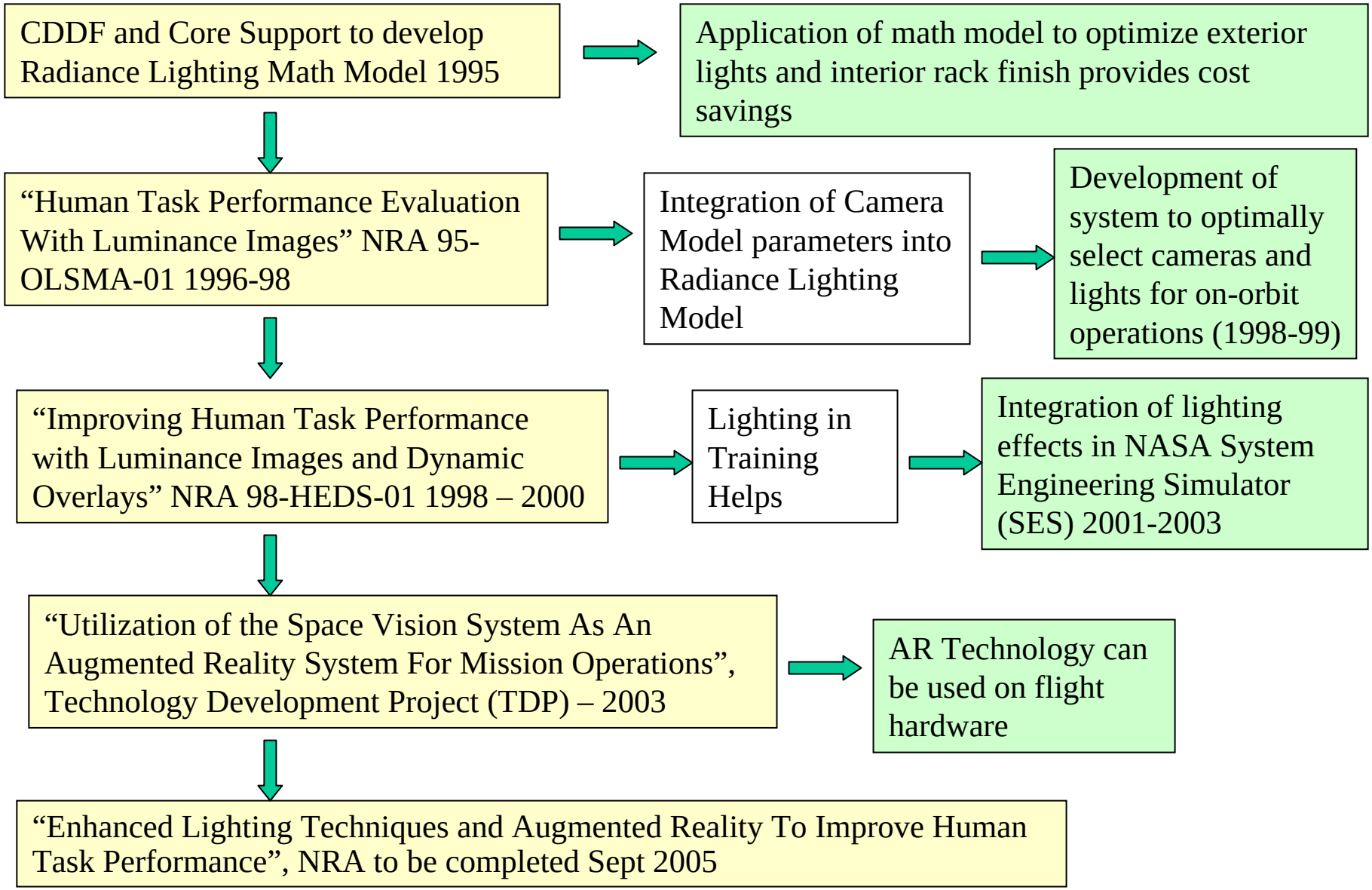




Training Pictures of STS-90 Crew In Flight

Background Charts

Research Relevancy Map for Lighting, Training and Augmented Reality



Center Director Discretionary Fund (CDDF) Project – 1995-1996
Measured reflectance of materials used on major surface areas of Shuttle, Station and other major payloads as input to lighting math model.

Core Research Support – 1994-1996
Measured and validated major lighting systems for Shuttle and Station as input to lighting math model

Radiance is developed into a NASA lighting math model using NASA specific database of lights and materials. Now a registered and configuration controlled math model for mission support.

Optimized the number exterior fixed lights for EVA translation on ISS (reduced from 14 to 7)

Analytically determine the impact on ISS interior lighting levels for a family of rack face surface coatings.

“Human Task Performance Evaluation With Luminance Images” NRA 95-OLSMA-01 1996-98

1) development of synthetic camera images from luminance maps for use in training and 2) compare the effect of different types of training images on actual task performance.

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(Flights 2A.1 - 11A)

Training with camera images of static simulated lighting improves human performance

Follow on research

“Improving Human Task Performance with Luminance Images and Dynamic Overlays”
NRA 98-HEDS-01 1998 – 2000

“Improving Human Task Performance with Luminance Images and Dynamic Overlays” NRA 98-HEDS-01 1998 – 2000. Continuation of "Human Task Performance Evaluation With Luminance Images" (NRA 95-OLMSA-01). Determine the effects of dynamic vs static lighting on training and the effectiveness of augmented reality technology for training and task execution.

Lighting effects in training benefit performance whether dynamic or static.

Integration of simple lighting effects in NASA JSC System Engineering Simulator (SES) for crew training. 2001-2003

Augmented Reality Technology improves operator performance during task execution.

“Utilization of the Space Vision System As An Augmented Reality System For Mission Operations” Technology Development Project (TDP) – 2003

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The goal was to determine whether augmented reality technology can improve performance when implemented using existing flight hardware.

Space Vision System Hardware Currently Flies on Shuttle and ISS

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2) Appropriate augmented reality overlays have been shown to offer significant improvements in robotic control performance.

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“Enhanced Lighting Techniques and Augmented Reality To Improve Human Task Performance” - NRA – to be completed Sept 2005

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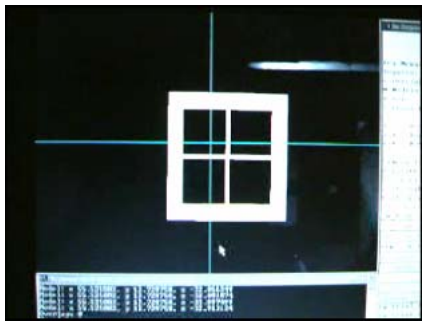

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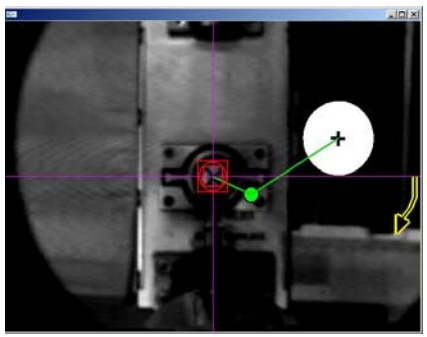

Tracking overlay will be used when field of view of end effector camera is restricted.